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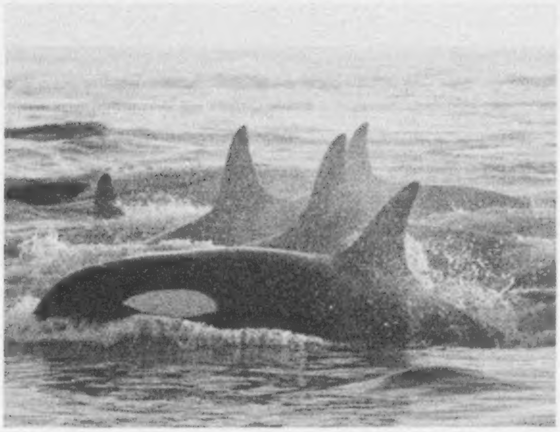
Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/047

RECOVERY POTENTIAL ASSESSMENT OF OFFSHORE KILLER WHALES OFF THE PACIFIC COAST OF CANADA



A group of Offshore Killer Whales. (Photo credit: B. Gisborne).

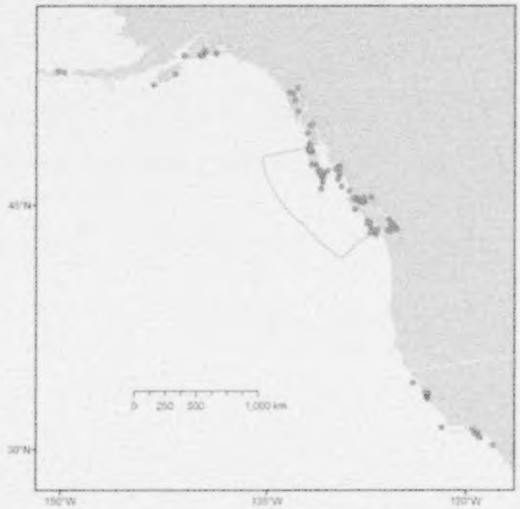


Figure 1. Map of the eastern North Pacific showing locations of encounters with Offshore Killer Whales. Grey line denotes Canada's Exclusive Economic Zone.

Context :

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designates aquatic species as threatened or endangered, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction under the Species at Risk Act (SARA), is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, population or designable unit (DU), threats to its survival and recovery, and the feasibility of its recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes including recovery planning.

Offshore Killer Whales were assessed by COSEWIC as Threatened in November 2008, and listed as such under SARA in July 2011. Consequently, a recovery strategy was to be developed by July 2013. A DFO recovery team was struck to develop the recovery strategy, and a Technical Workshop to complement the development of that document was held May 27-28, 2013. No prior RPA or critical habitat assessment or analysis has been conducted. In support of the recovery of Offshore Killer Whales by the Minister, DFO Science has been asked to undertake an RPA, based on the National Frameworks (DFO 2007, 2009). The advice in the RPA may be used to inform both scientific and socio-economic elements of a listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per section 73, 74, 75, 77 and 78 of SARA. The advice generated via this process will also update and/or consolidate any existing advice regarding this species.

SUMMARY

- Offshore Killer Whales (OKWs) in the eastern North Pacific comprise a single population with a known range that includes continental shelf waters from southern California to the eastern Aleutian Islands, Alaska.
- Relative to other Killer Whale populations in Canadian Pacific waters, OKWs are rarely encountered. They were first identified off the British Columbia (BC) coast in 1988, and have only been encountered in the region a total of 103 times up to 2012.
- OKWs exhibit a diffuse latitudinal shift in their distribution seasonally, with encounters being most frequent off California during the winter months and off Alaska during summer. In BC waters, OKWs have been encountered or detected acoustically in all months of the year, with some evidence of peaks in March, August and December.
- Although the preferred habitat of OKWs in Canadian Pacific waters appears to be outer continental shelf waters, they also make occasional forays into protected inside passage waters.
- OKWs appear to feed primarily on sharks, including Pacific Sleeper Shark, Blue Shark, and Spiny Dogfish, although some teleost fishes such as Chinook Salmon and Pacific Halibut are also consumed.
- Population modeling using photo-identification data indicates that the OKW population is small, with an average annual abundance estimate of 300 (95% Highest Posterior Density Interval (HPDI) = 257–373).
- The population trend appears stable, with average annual survival rates of 0.98 (95% HPDI = 0.92–0.99) balanced by annual recruitment rates of 0.02 (95% HPDI = 0–0.07).
- Potential threats to OKW habitat include prey limitation, acute and chronic underwater noise, chemical and biological contamination, oil spills, and disturbance. Potential sources of human-caused mortality include entanglement in fishing gear and vessel strikes.
- A Potential Biological Removal (PBR) of 0.55 animals/year suggests that the population could sustain very little anthropogenic mortality without declining.
- There is no evidence that the small OKW population is habitat- or prey-limited, either over its total range or within Canadian waters. Although the total available biomass of their elasmobranch prey is not known, the three species known to be consumed by OKWs – Pacific Sleeper Shark, Blue Shark and Spiny Dogfish – are widespread and abundant, and there is no indication of any decline in the abundance of these species.
- Additional field studies to better document patterns of habitat use and foraging ecology of OKWs are needed in order to identify potential critical habitat and describe its function, features and attributes.
- Continued photo-identification efforts will be necessary to improve estimates of population abundance and life history parameters and to monitor future trends.

BACKGROUND

Rationale for Assessment

In 2001, the northeastern Pacific Offshore Killer Whale population was designated Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The status of this population was reassessed in 2008 and uplisted to Threatened. Reasons for this designation were the very small size of the population and its exposure to threats from "high levels of contaminants, acoustical and physical disturbance, and potential oil spills". This population became legally listed as Threatened on Schedule 1 of the Species at Risk Act (SARA) in 2011.

As required by SARA for species of Special Concern, a Management Plan for Offshore Killer Whales in Canada was prepared by Fisheries and Oceans Canada (DFO) in December 2009 (Fisheries and Oceans Canada 2009). With the uplisting of Offshore Killer Whales under SARA in 2011, DFO is now required to develop a recovery strategy, which is a planning document that identifies what needs to be done to arrest or reverse the decline of a species. In order to provide an up-to-date assessment of the population's status and potential threats to recovery, DFO Science has been requested to prepare a Recovery Potential Assessment (RPA) that will serve as the scientific basis for the development of the recovery strategy. An RPA provides scientific background, identification of threats and probability of recovery of a population that is deemed to be at risk. Specifically, an RPA addresses the 17 tasks identified in the *Revised Protocol for Conducting Recovery Potential Assessments (*DFO 2009).

This document provides an assessment of the distribution, seasonality, foraging ecology and population status of OKWs based primarily on on-going studies by the Cetacean Research Program (CRP), Pacific Biological Station (Nanaimo, BC). This status assessment is followed by the RPA, which address the 17 tasks identified in DFO (2009), as well as 10 additional tasks related to the identification of important habitats and threats to those habitats. For more detailed information, see Ford et al. (2014).

Species Biology and Ecology

The Killer Whale is the largest member of the family Delphinidae and one of the most widely distributed mammals. It is currently considered a single wide-ranging species, *Orcinus orca*, with a cosmopolitan distribution in all the world's oceans and most seas. The Killer Whale is the apex marine predator, capable of feeding on a great diversity of prey, from the largest whales to small schooling fish. It has no natural predators. Different regional populations of Killer Whales are often distinct ecotypes with highly specialized foraging strategies and diets. These ecotypes are often sympatric, sharing the same waters but maintaining social isolation from each other. Recent molecular studies have shown that ecotypes in the North Pacific and Antarctic represent genetically-distinct lineages that may represent distinct species or subspecies.

Three lineages of Killer Whales have been found in coastal waters of the northeastern Pacific Ocean. These lineages, named *Transient*, *Resident* and *Offshore*, differ in morphology, social structure, diet, foraging behaviour and acoustic behaviour. Despite having overlapping ranges, these lineages do not mix and are thus reproductively isolated from each other. Transient Killer Whales (also known as Bigg's Killer Whales) specialize on marine mammal prey, though they occasionally kill and eat seabirds as well. Resident Killer Whales prey mainly on fish, particularly salmon, and some squid. Offshore Killer Whales also feed on fish and may specialize in preying on sharks. Neither Residents nor Offshores have been observed to prey on marine mammals. These foraging specializations appear to be fixed behavioural traits maintained by cultural transmission within populations.

Killer whales are long-lived animals that have a low reproductive potential. Although the life history parameters of OKWs are not known, they are likely similar to those of Resident Killer Whales, which are well studied. Survival patterns are typical of mammals, being U-shaped with highest mortality rates in very young (neonate) and very old age classes. Survival rates of juveniles and adults are high (0.97–0.99), particularly among mature females and during periods of population growth. Resident females have a mean life expectancy of about 46 years and a maximum longevity of about 80 years. Males have a mean life expectancy of 31 years, with maximum longevities of 60–70 years. Females give birth to their first viable calf at approximately 14 years, and produce an average of 4.7 calves over a 24-year reproductive period. Gestation is 16–17 months and the minimum calving interval is about 3 years (mean = 4.9 years). Females give birth to their last calf at around 40 years and then become reproductively senescent for the remainder of their lives. Calving is diffusely seasonal, with a peak in fall and winter. Killer whale social structure is matrilineal, with social groupings in some populations having highly stable composition with little or no dispersal of individuals from the matriline. Offshore Killer Whales tend to form large groupings occasionally containing over 100 individuals. Given that the total population abundance is estimated to be only 300 animals (see below), a substantial proportion of the population can occur in one aggregation and could be at risk from anthropogenic threats such as a catastrophic oil spill.

Data Sources for Assessment

Data for assessment of population status and habitat use by Offshore Killer Whales are based primarily on field encounters during which photographs were collected for identification of individuals from natural markings. Studies of Killer Whales using this technique have been undertaken annually in BC since 1973 by researchers with the Cetacean Research Program and more recently by colleagues in adjacent US waters to the north and south. These studies have focused on Resident and Transient Killer Whales, and Offshore Killer Whales have been only rarely and sporadically encountered in the region. Overall, only 137 encounters with OKWs have taken place over the past 40 years of field effort, which represents about 1% of the 10,580 total encounters with Killer Whales. Of these 137 encounters, 103 took place in Canadian waters, 13 to the south as far as California and 21 in Alaska. Passive acoustic monitoring was also used as a supplement to photo-identification data in assessment of seasonal occurrence of OKWs as the data are less subject to temporal biases in effort over the year. Distinctive stereotyped calls produced by Resident, Transient, and Offshore Killer Whales are readily distinguishable (Ford 1991; Deecke et al. 2005; Cetacean Research Program, unpubl. data). A network of 13 autonomous underwater recording moorings deployed off the coast of British Columbia during 2006–2012 collected long-term acoustic data that included 69 days with detections of distinctive OKW vocalizations. Feeding habits were assessed by the collection of prey fragments from the water at the location of predation events. Prey species identification was made by examination of fish scales or genetic analysis of tissue samples.

ASSESSMENT

Population Status, Trend and Recovery Targets

COSEWIC (2008) considered the Offshore Killer Whale population to comprise a single Designatable Unit (DU). The data used in our current assessment support this conclusion and indicate that the OKW population consists of a single network of socially-connected individuals that ranges over continental shelf and nearshore waters off the west coast of North America from southern California to the eastern Aleutian Islands, Alaska. The extent of potential movements outside of this range is unknown. There are no known adjacent populations that could provide a rescue effect should the OKW population decline.

Estimates of the current abundance of OKWs are based on photographic identification of individuals from natural markings between 1988 – the first year OKWs were encountered – and 2011. We adopted a statistical modeling approach using a Bayesian formulation of the Jolly-Seber mark-recapture model to estimate abundance and population dynamics of OKWs from photo-identification data, which takes into account mortality and recruitment, as well as the proportion of unnamed animals in the population. The annual probability of individuals being identified and estimates of abundance, survival and recruitment are shown in Figure 2. Identification probabilities were very low in some years, particularly due to relatively few encounters during the first half of the time series, which limited our power to precisely estimate abundance and demographic parameters in the early years of the study. Higher identification probabilities allowed more precise inference in the latter half of the time series (year 2000 onwards). During this time, survival rates were estimated to be high, with an average posterior median of 0.98 (95% Highest Posterior Density Interval [HPDI] = 0.92-0.99), with mortality balanced by per capita recruitment at an average rate of 0.02 (95% HPDI = 0-0.07). As a result, the abundance of distinctly marked whales alive in each year was estimated to be stable around an average estimate of 240 whales (95% HPDI = 223 to 258). Estimates of the proportion of whales that were distinctive in reference encounters had posterior medians ranging from 0.68 to 0.86, resulting in an overall sampling distribution for the average proportion centered on 0.80 (95% HPDI = 0.64 to 0.92). After rescaling to include both distinct and non-distinct whales, the average annual population abundance estimate, A, had a posterior median of 300 (95% HPDI = 257-373).

With no knowledge of historical population abundance or current carrying capacity of the habitats of Offshore Killer Whales, establishing quantitative recovery targets for the species in terms of abundance is difficult. Recovery Strategies for both Resident Killer Whale and Transient Killer Whales have recovery goals of ensuring their long-term viability through the maintenance of steady or increasing abundance and other population and distribution objectives (Fisheries and Oceans Canada 2007, 2011). The Management Plan for OKWs has as its goal:

> *To maintain a population level that is viable over the long-term within the known range for the northeastern Pacific Offshore Killer Whale population in Pacific waters of Canada.*

with the two main objectives over the 10 years after finalization of the plan being to:

> *a) Maintain the population at, or above its current level (averaged over 5 years)*
>
> *b) Maintain the population's current range of occupancy and distribution on the west coast of B.C.*

Potential natural limiting factors for OKWs are poorly known. As killer whales have no natural predators, populations are likely to be limited ultimately by food limitation. The abundance of the OKW population is small enough so that inbreeding could potentially be an issue affecting fitness, but it is likely that OKWs have outbreeding mechanisms that mitigate this risk as in other killer whale populations. Severe tooth wear is ubiquitous among adult OKWs, but it is not certain if this is a potential factor affecting survival or longevity. Mass strandings and entrapment are potential sources of natural mortality in OKWs.

Distribution, Seasonality and Foraging Ecology

The locations of encounters with OKWs are shown in Figure 1. These are distributed from the coast of southern California (~33°30' N) north to Prince William Sound, Alaska (~60° N), and west to the eastern Aleutian Islands (~160° W). These encounters comprise the known current range of the population. The extent of potential occurrence in oceanic waters beyond the continental shelf is unknown. The first few encounters with Offshore Killer Whales in BC were in

1988s and were in areas that had not received previous study effort (e.g., off the outer coast of Vancouver Island and in Haida Gwaii). OKWs were first observed in the protected inside waters off eastern and southern Vancouver Island in 1992, 19 years after annual survey effort for Killer Whales began in this area. They have been encountered or detected acoustically in these inside waters on at least 31 occasions since then. It seems likely that the typical range of OKWs is in outer continental shelf waters, but that their range changed in the early 1990s to include periodic visits to protected nearshore areas. It is unknown whether this change reflects a return to part of their historical range, an expansion of their current habitat, or a shift inshore and away from other habitats.

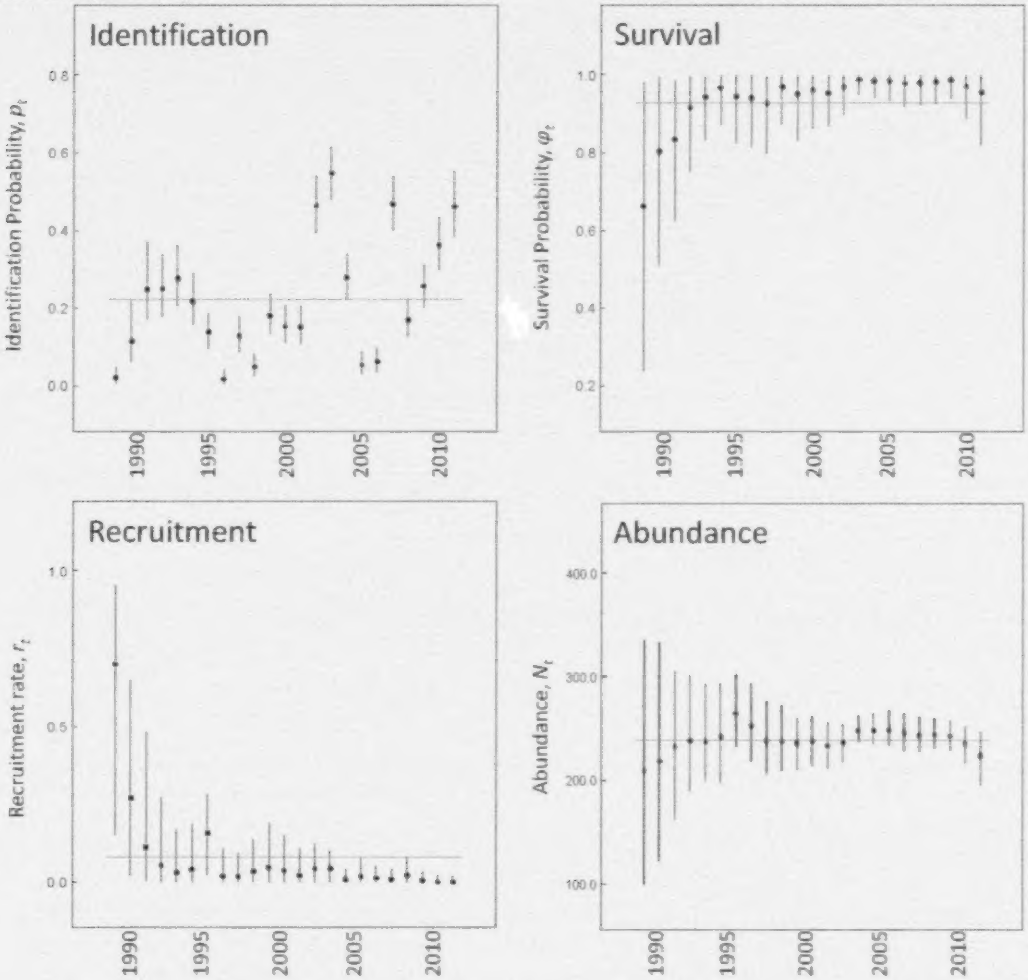


Figure 2. Estimates of the probability of identification (p_t), per-capita recruitment rate (N_t) survival rate (φ_t),and abundance of distinctive OKW individuals (N_t), for each year 1989-2011. Vertical lines represent the full range of the posterior distribution for each parameter, circles represent the posterior median and horizontal lines represent the average levels over the time series. *Estimates from years 1988 and 2012 were omitted because identification probability was fixed in the model to ensure parameter identifiability.*

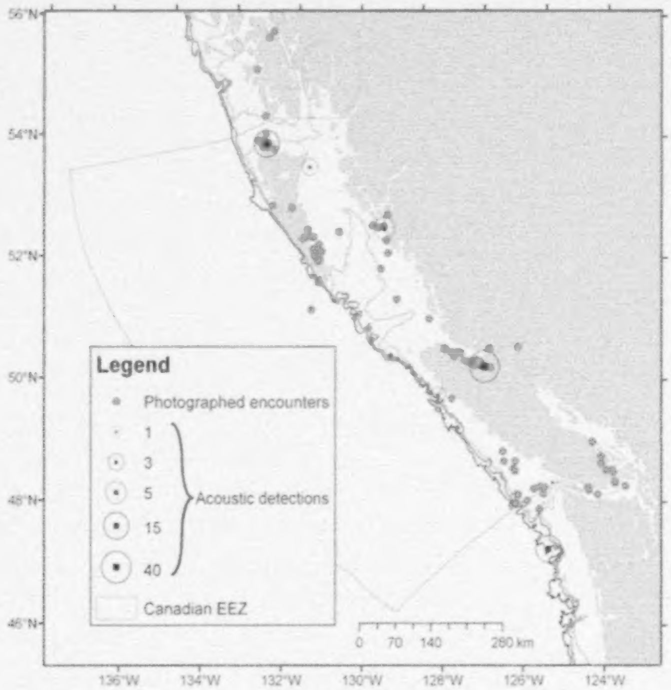


Figure 3. Distribution of encounters with OKWs (red dots; 1988–2012;) and numbers of days in which OKWs were detected acoustically at fixed monitoring sites (open circles; 2006–2012) in Pacific Canadian waters (indicated by the EEZ line). Also shown are depth isobaths to indicate the continental shelf break. Depth contours are indicated with shades of blue: the 200 m isobaths is light blue, 500 m medium blue, and 1000 m dark blue.

The locations of encounters and numbers of acoustic detections of OKWs in Canadian waters are illustrated in Figure 3. Encounters were scattered widely off the coast, although some concentrations are apparent. Clusters of encounters are located off southeastern and northeastern Vancouver Island, which is at least partly due to observer effort; these waters are frequented by numerous whale watch vessels over much of the year. A year-round network of hydrophones maintained by OrcaLab in Johnstone Strait and Blackfish Sound, northeastern Vancouver Island, has also resulted in many detections (Table 1). As mentioned above, these encounters and detections have all taken place since 1992.

Other areas with relatively numerous encounters with OKWs include the banks off the southwest coast of Vancouver Island, the nearshore waters off southeast Moresby Island, Haida Gwaii, and around Langara Island. The southeast Moresby Island and Langara Island areas have had relatively high levels of observer effort, but the ratio of encounters to effort seems qualitatively fairly high compared to other areas. Encounters offshore of southwest Vancouver Island are similarly numerous relative to effort. OKWs were found in a variety of marine habitats off the BC coast, from deep oceanic waters beyond the shelf break to the heads of narrow inlets and bays. Judging from encounter rates relative to observer effort (which, as indicated above, is mostly unquantifiable), waters over the outer continental shelf waters and slope may be particularly important habitat for OKWs. Clusters of encounters near Langara Island, in western and eastern Hecate Strait, and off southwest Vancouver Island are all in relatively close proximity to the continental shelf margin or to Moresby Trough, a deep canyon that extends into Hecate Strait from the southwest.

Offshore Killer Whales appear to exhibit a latitudinal shift in their distribution seasonally, although this shift is rather diffuse. Overall, OKW encounters are most frequent in California during the winter months and in Alaska during summer. In BC, OKWs have been encountered or detected acoustically in all months of the year, with some evidence of peaks in March, August and December.

Although the foraging ecology of OKWs is poorly known, it appears likely that they are fish feeders with a potential specialization on sharks. Elasmobranchs were the predominant prey documented in observed predation events by OKWs. Of 40 prey items identified, 37 (93%) were sharks and only 3 (7%) were teleost fishes (Chinook Salmon, *Oncorhynchus tshawytscha*). Of the elasmobranchs, Pacific Sleeper Shark (*Somniosus pacificus*) was most common (68%), with Spiny Dogfish (*Squalus suckleyi*) and Blue Shark (*Prionace glauca*) together representing less than one-third of observed prey. There is evidence from stomach contents that Pacific Halibut (*Hippoglossus stenolepis*) is also consumed. A preponderance of sharks in the diet has been hypothesized to be a cause of the severe tooth wear that is pervasive in the population. Ford et al. (2011a) proposed that the hardened dermal denticles (placoid scales) embedded in the skin of sharks cause abrasion of the teeth during prey handling and consumption, leading to the pattern of tooth wear seen in OKWs.

Habitat and Residence Requirements

Patterns of movement and habitat use of OKWs are expected to be driven by availability of prey. No specific habitats are likely to be used for particular life processes such as mating and calving. Cetaceans are highly mobile and generally do not have "residences" as defined in the Species at Risk Act. The OKW population ranges widely in both outer coast and inside waters off Canada's west coast. There are no known residence requirements.

It is reasonable to assume that the most important property of OKW habitat is the presence of sufficient prey resources to provide for profitable foraging. Although knowledge of the diet of OKWs in Canadian waters is limited, it appears to be dominated by elasmobranch fish, including Pacific Sleeper Shark, Blue Shark and Spiny Dogfish. Chinook Salmon and Pacific Halibut are also known to be consumed by OKWs, but the importance of these prey species is uncertain. The densities of prey species needed to meet the requirements of suitable habitat for OKWs are not known.

The known prey species of OKWs are widely distributed in coastal and offshore waters off the Pacific coast of Canada. The Pacific Sleeper Shark is a relatively deep water species found mostly at depths of 150–450 m in continental shelf and slope waters. Fishery bycatches off the BC coast indicate that the species occurs along the shelf break and in deep areas on the shelf such as Dixon Entrance and Moresby Trough in Hecate Strait. This species is also found in some inside passes and channels with particularly deep water (e.g. Johnstone Strait). Blue Sharks are widely distributed throughout the North Pacific in coastal and epipelagic waters beyond the shelf slope. As with Sleeper Sharks, there is no directed fishery for Blue Sharks, but fishery bycatch in BC shows the species occurs in Hecate Strait, Dixon Entrance, along the continental shelf slope, and in oceanic waters. The Spiny Dogfish is found throughout nearshore and continental shelf waters off the BC coast, as well as in oceanic areas beyond the shelf.

Potential Threats to Habitat and Limiting Factors

Potential threats to habitat from anthropogenic sources are described below. There is no evidence to date that habitat of OKWs has been reduced in quantity or quality by anthropogenic activities such as fisheries. Some habitat areas such as offshore of southwest Vancouver Island likely have higher levels of anthropogenic ambient noise due to increased shipping than was the

case in past decades, but it is not known if such levels are sufficient to cause functional habitat degradation.

Prey Availability

If high quality habitat is that which is used regularly for foraging (as is the case for Resident and Transient Killer Whales), reduction in availability of targeted prey species would reduce the value of such habitat. The primary means by which prey reduction could occur is through fisheries. Currently, there is no evidence that the abundance of the three shark species that dominate the known diet of OKWs has declined in recent years or is likely to in the foreseeable future. There is no directed fishery for either Pacific Sleeper Shark or Blue Shark in Canadian Pacific waters, but bycatch of these species does occur in trawl and longline fisheries and is monitored by DFO. Area-weighted catches per unit effort (CPUEs) of Pacific Sleeper Sharks from bycatch monitoring in the Gulf of Alaska are either stable or increasing, depending on the area. There are substantial fisheries bycatches for Blue Sharks in other regions of the North Pacific, but removals are estimated to be 74% of maximum sustainable yield. Rates of removal through bycatch of Blue Sharks in Canadian Pacific waters are considered low, at 20–40 tonnes per year. Recent stock assessments of the Spiny Dogfish in Canadian Pacific waters indicate that relative abundance is stable. In particular, the outside stock (continental shelf waters excluding the Strait of Georgia), which is likely to be consumed by OKWs, is healthy and fishing pressure is considered to be low relative to the estimated size of the population.

There is no evidence that the OKW population is currently habitat- or prey-limited, either over its total range or within Canadian waters. With a population of only some 300 animals and a range that encompasses the continental shelf waters for more than 5000 km of coastline, habitat limitation seems highly unlikely. Although the total available biomass of their elasmobranch prey is not known, the three species known to be consumed by OKWs – Pacific Sleeper Shark, Blue Shark and Spiny Dogfish – are widespread and abundant, and there is no indication of any decline in the abundance of these species. However, despite this high biomass there may be unknown factors that limit the availability of these prey species to OKWs and prey limitation is a possible reason for their lack of population growth. It is also possible that there are important prey species of OKWs that have yet to be identified. If OKWs forage preferentially for large elasmobranchs, it is possible that Basking Sharks (*Cetorhinus maximus*) represented an important food source in the past. Basking Sharks were once abundant in the range of OKWs including Canadian Pacific waters, but decades of exploitation, intentional culling and bycatch mortality in net fisheries almost extirpated them from the region and they remain extremely rare today (COSEWIC 2007). Because killer whale populations are ultimately regulated by food availability, it is important that a better understanding of OKW foraging ecology is attained to assess the potential for prey limitation.

Underwater Noise

Given the apparent importance of underwater acoustics for communication and echolocation in Killer Whales, the acoustic environment is considered to be an important feature of critical habitat of Resident and potential critical habitat of Transient Killer Whales. Acoustic properties are no doubt important features of any OKW habitat as well. The acoustic environment of OKW habitat can be affected by two main types of anthropogenic noise, acute and chronic, and these can affect habitats by masking vocalizations or natural ambient sounds that may be used for orientation, communication and echolocation, or by causing behavioural disturbance responses that result in disruption of life processes or avoidance of noisy areas. Acute noise sources include impulsive sounds generated in the mid to low frequency range (< 10 kHz), such as those produced during - seismic surveying, explosions, and construction-related activities such

as pile driving, and non-impulsive sounds with sudden onset and short duration such as mid-frequency military sonar which typically ranges from 2 to 8 kHz. Chronic anthropogenic noise in the ocean is caused primarily by motorized vessels, but other sources such as offshore wind and tidal turbine arrays can also be significant in some regions. Mid-frequency tactical sonar used in navy operations has been observed to cause serious disturbance responses by Resident Killer Whales and the use of acoustic deterrent devices at aquaculture sites has been linked to displacement of Resident Killer Whales from their habitat (Fisheries and Oceans Canada 2009). Potential effects of chronic noise on Killer Whales are not well understood. Increased vessel noise has shown to be associated with the use of higher amplitude vocalizations in Resident Killer Whales, and there is some evidence of reduced foraging efficiency in high-noise habitats. Noise from increased shipping in the world's oceans has increased ambient noise levels by as much as 12 dB in recent decades. Shipping activity in some areas off the coast of British Columbia is significant and likely to increase. Noise levels are estimated to be particularly high off southwestern Vancouver Island due to cargo vessels transiting between the entrance to Juan de Fuca Strait and Asia or other desitinations. This area is potentially important feeding habitat for OKWs. Underwater noise could also affect OKWs indirectly through effects on their prey. Sharks are sensitive to low frequency sounds and it is possible that changes in shark behaviour or distribution could result from loud anthropogenic noise.

Chemical and Biological Contamination

Degradation of water quality due to environmental contaminants poses a potentially significant threat to OKWs, their prey and habitat. The types of contaminants and the pathways by which they may enter Killer Whale habitat and prey, and the potential effects on the health and survival of Killer Whales are discussed in detail in Fisheries and Oceans Canada (2007, 2011). Potential contaminants include persistent organic pollutants (POPs) such as PCBs and PBDEs (polybrominated diphenylethers), dioxins and furans, heavy metals, and DDT. Krahn et al. (2007) provided evidence that levels of PBDEs and DDT were particularly high in OKWs, and suggested that this may be attributable to their presence in coastal California waters, where these chemicals enter the marine environment through agricultural run-off. As high trophic level predators, sharks are particularly susceptible to bioaccumulation and biomagnification of pollutants due to the high lipid content of their liver and their long life span. Levels of POPs and heavy metals such as mercury in shark tissue can exceed recommended levels for human consumption. No assessment has yet been made on heavy metal concentrations in OKWs.

Oil Spills

Although oil spills have the potential to cause direct mortality to Killer Whales, a large-scale catastrophic spill would have the potential to render OKWs habitat areas un-inhabitable for an extended period of time. Although the chance of a major spill in outer coast, continental shelf waters is remote, should a spill take place in confined waters such as the narrow inlets and channels occasionally used by OKWs, immediate and acute effects on individuals could occur and the habitat could be seriously degraded. Because OKWs tend to travel in large aggregations, a significant portion of the population could be affected by a single large-scale spill. Currently there are development proposals in environmental review that, if approved, could result in a significant increase in oil tanker traffic in nearshore waters.

Disturbance

Disturbance from the close physical proximity of vessels, particularly those involved with whale watching activities, is a major concern for Resident and Transient Killer Whales in nearshore

waters (Fisheries and Oceans 2007, 2011). OKWs are usually encountered in areas outside the current range of most whale watching excursions, but may be an attraction during their visits to inside waters off eastern and southern Vancouver Island. Given the rarity of such visits, targeted vessel disturbance is a negligible concern at present.

Sources of Human Induced Mortality and Harm

Potential sources of mortality from human causes to Killer Whales generally are described in COSEWIC (2008) and Fisheries and Oceans Canada (2007, 2011), and to OKWs specifically in Fisheries and Oceans Canada (2009). These include vessel strikes, interactions with fisheries (e.g., entanglement in fishing gear), oil spills, and direct killing. Of these potential sources, none has been shown to be the cause of any documented mortalities to OKWs. There is one case of a non-lethal injury to an OKW individual through a likely vessel propeller strike, which severed the dorsal fin (CRP, Pacific Biological Station, Nanaimo, BC, unpublished data). A mass stranding of 20 OKWs took place at Estevan Point, west coast of Vancouver Island, in 1945, but there is no evidence that it was caused by human activities. Mass strandings of Killer Whales are extremely rare.

Scenarios for Mitigation and Alternatives to Activities

Prey Depletion

There is currently no directed fishery for two of the three shark species – Pacific Sleeper Shark and Blue Shark – that comprise the majority of known OKW prey. However, these two species are taken as bycatch in groundfish longline and trawl fisheries, although the numbers taken are considered low relative to their abundance. The CPUE of bycatch is monitored and management actions could be taken should a decline suggest depletion of these populations. Historically, there have been major fisheries for Spiny Dogfish in Canadian Pacific waters to supply shark livers for Vitamin A production. Currently there is only a relatively small food fishery for this species. There is no immediate conservation concern for stocks of Spiny Dogfish in Canadian Pacific water based on current levels of removals.The stock status of the species is regularly assessed by DFO Science to ensure management of fisheries at sustainable levels.

Two other OKW prey species documented in Canadian Pacific waters, Chinook Salmon and Pacific Halibut, are managed through DFO's Integrated Fisheries Management Plan for Groundfish.

Underwater Noise

Military sonar

The Department of National Defence (DND) has established protocols to protect marine mammals from disturbance and/or harm from the use of military active sonar and deployment of ordnance. Maritime Command Order 46-13, for marine mammal mitigation, is to avoid transmission of sonar any time a marine mammal is observed within the defined mitigation avoidance zone, which is established specific to each type of sonar. Ship's personnel receive training in marine mammal identification and detection. All foreign vessels are subject to Canadian regulations while in Canadian waters. There remains some concern regarding compliance by foreign vessels with Canadian regulations and the effectiveness of these mitigation protocols.

Seismic testing

There are currently few industrial or scientific seismic surveys conducted in western Canadian waters. Some projects involving seismic surveying trigger screening under the Canadian

Environmental Assessment Act (CEAA), while others are reviewed regionally by DFO. In 2005, DFO developed a draft Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment, to address concerns regarding the potential impact of seismic use on marine mammals and other marine life. In the Pacific Region, each proposed seismic survey is reviewed by DFO marine mammal experts and mitigation measures are developed based on the species of concern in the area of the survey for each project. Seismic mitigation protocols recommended by DFO Pacific Region are designed to prevent exposure of cetaceans to received sound pressure levels in excess of 160 dB re 1 μPa, which is generally the level at which behavioural disturbance can be anticipated. A slow ramp-up of air gun pressure, or a 'soft start', is utilized in the assumption that this will allow cetaceans to leave the area before it is ensonified with intense sound. A safety zone corresponding to the estimated 160 dB re 1 μPa isopleth is established around the sound source, and a marine mammal observer monitors this zone while air guns are operating. If a cetacean enters the safety zone, air gun use is suspended until it has left the zone.

While many seismic projects are screened prior to commencement, it is not clear that all projects are assessed for impacts to marine mammals prior to initiation of seismic activity. Also, even with a sound exposure mitigation protocol, OKWs may be difficult to detect by observers in high sea states and thus may be unknowingly exposed to intense sound.

Construction noise

Mitigation protocols to prevent exposure of cetaceans to noise associated with construction activities such as dredging and pile driving in the Pacific Region are similar to those for seismic air guns.

Chronic noise

There is currently no mitigation of chronic noise in the marine environment that originates from shipping and other marine vessel traffic.

Toxic Spills

The Transportation of Dangerous Goods Act regulates handling and transport of toxic substances within Canada, and numerous international, federal and provincial measures are in place for the prevention and management of toxic spills (e.g. Canadian/U.S. spill response plans for trans-boundary waters, Oil and Gas Operations Act, BC EMA). Despite such regulation and preventative measures, spills are frequent along the coast of British Columbia, but most are very small and localized and do not present a major risk to OKW habitat.

Biological and Chemical Pollution

There are numerous national and international regulations and agreements that govern the manufacturing and application of many kinds of Persistent Bioaccumulating Toxins (PBTs), particularly the so-called legacy PBTs, such as PCBs. The Stockholm Convention on persistent organic pollutants (POPs) and other United Nations Protocols aim to reduce global levels of legacy PBTs. Manufacture and availability of toxic chemicals in Canada are managed via listing under Schedule 1 of the Canadian Environmental Protection Act (CEPA) and the BC Environmental Management Act (EMA) has regulations in place for management of contaminants in industrial and municipal effluents and outflows. The Fisheries Act (S. 36) prevents discharge of toxic substances into fish habitat(s), mitigating toxic threats to killer whale prey. In 2010, Environment Canada published a Final Revised Risk Management Strategy for Polybrominated Diphenyl Ethers, under CEPA. This strategy has provisions for controls of the forms of PBDEs that are known to bioaccumulate in killer whales.

Regulations on manufacture of chemicals and vectors of contamination (e.g. sewage outflows) manage toxins in runoff in British Columbia. The BC Ministry of Environment's storm-water planning, as well as non-governmental programs are in place for education on toxic runoff. For agriculture, the Fertilizers Act manages chemicals and the BC EMA Agricultural Waste Control regulation and Best Agricultural Waste Management Plans (BAWMPs) specifically manage industry practices.

Disturbance

Disturbance from the proximity of vessels such as those engaged in whale watching is a minor concern for OKWs at present due to the rare and unpredictable occurrence in nearshore waters. The Fisheries Act's Marine Mammal Regulations legally protects all marine mammals from disturbance and recently drafted amendments will establish legal approach distance thresholds to improve protection. The Species at Risk Act also provides legal protection for listed species including OKWs from disturbance. The 'Be Whale Wise: Marine Wildlife Guidelines for Boaters, Paddlers and Viewers' guidance has a range of recommendations to mitigate potential impacts from small vessels.

Fishery Interactions

Fishery interactions, such as entanglement in gear or depredation of catches, have not been documented with OKWs. Amendments to the Marine Mammal Regulations under the Fisheries Act will require mandatory reporting of fishery interactions by commercial fishers, including bycatch, entanglement and depredation.

Allowable Harm Assessment

Due to the small population size of OKWs, any human-induced mortality would be a cause for concern. In order to estimate the level of human-caused mortality that may be allowable without causing serious population-level consequences or preventing recovery, the U.S. National Marine Fisheries Service has devised a means of calculating the Potential Biological Removal (PBR) for marine mammal populations. PBR estimates the maximum number of animals that may be removed per year, excluding natural mortality, while still allowing the population to reach or sustain its 'optimum sustainable population' (Wade 1998). PBR is calculated as:

$$PBR = N_{\min} \times \frac{1}{2} R_{\max} \times F_R$$

where:

$N_{\min}$ = minimum population estimate (20th percentile of estimated population size; see formula below for its derivation)

$R_{\max}$ = maximum theoretical or estimated net productivity of the stock at a small population size (0.04 as recommended for cetaceans [Wade 1998] and suggested by recent growth rates of Alaskan Resident Killer Whales (Matkin et al. in press)

F_R = recovery factor (0.1, based on population abundance, trend and vulnerability [Taylor et al. 2003])

To determine $N_{\min}$, we used the following formula from Wade (1998):

$$N_{min} = \frac{\hat{N}}{\exp(z\sqrt{\ln(1+CV(N)^2)})}$$

where:

$\hat{N}$ = point estimate of population size (300 individuals)

z = standard normal variate (0.842 for the 20th percentile)

$CV(N)$ = coefficient of variation for population estimate (0.1)

From these calculations, N_{min} was found to be 276, resulting in a PBR of 0.55 individuals. It is clear that the small OKW population could sustain very little human-induced mortality without declining.

Sources of Uncertainty

There are numerous sources of uncertainty in this assessment. The OKW population is very seldom encountered compared to other Killer Whale populations in Canadian Pacific waters, and encounters in continental shelf waters off the outer coast, which is likely their primary habitat, are particularly rare. The large group sizes typical of OKWs and their tendency to be widely dispersed when observed in outer coast areas results in a high proportion of incomplete encounters (where an unknown number of animals are not photo-identified). The infrequency of encounters and the dynamic nature of associations within groups present additional difficulties in photo-identifying individuals, particularly with poorly-marked juveniles, and as result a significant proportion of the population is unnamed. Although these uncertainties have been addressed through mark-recapture modeling, there are relatively wide confidence limits in estimates of abundance, survival and recruitment compared to other Killer Whale populations. Life history parameters such as age of maturity, fecundity rates by age, etc., are very poorly known compared with other killer whale populations in the region.

Knowledge of the preferred habitats of OKWs while in Canadian waters is poor. There have only been 103 encounters with OKWs over the last 24 years in these waters, and these have been made opportunistically, without dedicated systematic survey effort. As a result, encounter locations are likely highly influenced by spatial and seasonal biases in search effort that are largely unquantified and thus difficult to correct. Although knowledge of the diet of OKWs has improved in recent years, it still remains inadequate to address such questions as the role of different prey species in determining distribution and movement patterns and in potentially limiting population growth. Additional unbiased data on occurrence and feeding habits are needed to better document important habitats and their functions, features and attributes.

CONCLUSIONS AND ADVICE

The OKW population ranges widely in continental shelf waters from southern California to the eastern Aleutian Islands, and may occur in Canadian Pacific waters in any month of the year. Recent evidence suggests that this population feeds primarily on sharks, including Pacific Sleeper Shark, Blue Shark, and Spiny Dogfish, although some teleost fishes such as Chinook Salmon and Pacific Halibut are also consumed. Population modeling using photo-identification data indicates that the OKW population is small, with an average annual abundance estimate of 300 (95% Highest Posterior Density Interval (HPDI) = 257–373). The population appears stable, with average annual survival rates of 0.98 (95% HPDI = 0.92–0.99) balanced by annual recruitment rates of 0.02 (95% HPDI = 0–0.07). Potential threats to OKW habitat include prey limitation, acute and chronic underwater noise, chemical and biological contamination, oil spills, and disturbance. Potential sources of human-caused mortality include entanglement in fishing

gear and vessel strikes. A Potential Biological Removal (PBR) of 0.55 animals/year suggests that the population could sustain very little anthropogenic mortality without declining.

There is no evidence that the small OKW population is habitat- or prey-limited, either over its total range or within Canadian waters. Although the total available biomass of their elasmobranch prey is not known, the three species known to be consumed by OKWs – Pacific Sleeper Shark, Blue Shark and Spiny Dogfish – appear to be widespread and abundant. However, catch per unit effort (CPUE) of bycatch of Pacific Sleeper Sharks and Blue Sharks is monitored in fisheries. To support a better understanding of Offshore Killer Whale prey, analyses of the CPUE data should be undertaken to determine if there are trends in abundance of this important prey species.

Recovery objectives as described in the Management Plan for Offshore Killer Whales (Fisheries and Oceans Canada 2009) are to 1) maintain the population at or above its current level (averaged over 5 years) and 2) maintain the population's current range of occupancy and distribution on the west coast of B.C. Given that the abundance trend of OKWs appears to be stable, the first objective would appear to have been attained. Although data are very limited, there does not appear to have been any change in the range of occupancy or distribution of OKWs in BC waters over the past twenty years.

Additional field studies to better document patterns of habitat use and foraging ecology of OKWs are needed before critical habitat can be identified. Dedicated systematic vessel surveys and an expanded underwater acoustic monitoring network are required to obtain unbiased data on spatial and seasonal occurrence. Additional acoustic recording instruments should be deployed near the continental shelf slope, an area that may be important habitat for OKWs. Satellite tracking of individual OKWs is a potential means of acquiring additional information on movement patterns and preferred habitat and should be considered. Also, application of an effort model to partially correct seasonal and spatial biases in opportunistic sighting data should be undertaken.

Continued photo-identification efforts will be necessary to improve estimates of population abundance and life history parameters and to monitor future trends. Additional prey fragment sampling and fecal sampling should be undertaken to determine diet in different seasons and areas in Canadian waters and to assess the potential for food limitation in OKWs.

SOURCES OF INFORMATION

This Science Advisory Report is from the May 27th to May 28th, 2013 Recovery Potential Assessment Offshore Killer Whale. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2014. Recovery Potential Assessment of Offshore Killer Whales off the Pacific Coast of Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/047.

Aussi disponible en français :

MPO. 2014. Évaluation du potentiel de rétablissement des épaulards hauturiers au large de la côte du pacifique du Canada. Secr. can. de consult. sci. du MPO Avis sci. 2014/047.